Centers for Disease Control and Prevention
Epidemiology Program Office
Case Studies in Applied Epidemiology
No. 891-903

Paralytic Illness in Ababo

Instructor's Guide

Learning Objectives
After completing this case study, the participant should be able to:

- ☐ Define incidence, prevalence, and case-fatality rate;
- ☐ Define surveillance and identify the key features of a surveillance system;
- ☐ List the types of information that should be collected on a surveillance case report form;
- ☐ List the factors that can account for a change in the reported incidence of a disease;
- ☐ Define sensitivity of a surveillance system, and the effect of different case definitions on sensitivity.

This case study was originally developed by Nancy Binkin (EIS '80) in 1989. The current version was revised and edited by Richard Dicker with input from EIS Summer Course instructors and students over the years

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service

PART I

It is the early 1990s. The World Health Organization is planning a program for the global eradication of polio by the year 2000. Likura, a fictitious nation in south-central Africa, may become one of the countries selected to test the effectiveness of WHO's polio eradication strategies. Unfortunately, little is known about polio in Likura. The Minister of Health therefore assigned the task of assessing the polio situation to a Ministry worker who has recently returned from an epidemiology course in Atlanta, and who is about to become the District Health Officer in the Ababo District. The Ababo District is a relatively poor, rural district with a single hospital and several health centers. The Ababo District has attempted to conduct surveillance on polio cases and deaths over the past five years. The hospital, health centers, and all health workers are supposed to report such cases to the District Health Officer.

Question 1: What is **incidence**?

Answer 1:

Incidence refers to the occurrence of **new** cases of a disease or health event. Some define incidence as, simply, the **number** of new cases occurring during a given time period in a specified population. However, most epidemiologists use the term interchangeably with **incidence rate**:

$$\text{Incidence (or incidence rate)} = \frac{\text{\# new cases occurring during a given time period}}{\text{population during the same time period}}$$

For the numerator, you need the number of new cases occurring in the District.

For the denominator, you need an estimate of the population from which the cases arose. In theory, the denominator should be limited to the "population at risk," e.g., exclude those not at risk because of natural or acquired immunity. In practice, this is almost never done for population-based incidence rates.

Some people distinguish between two types of incidence measures -- cumulative incidence and incidence density.

- Cumulative incidence (attack rate, probability of disease, risk of disease) is the proportion of a group of people (“fixed cohort”) who experience the onset of a health-related event during a specified time period.
- Incidence density (person-time rate, hazard, force of morbidity) is a measure of the “speed” with which the population develops onset of the health-related event, and is expressed as # cases or events per 10^n persons per time, e.g., 14 new cases of diabetes per 100,000 population per year.

One measure of the polio situation in a community is the prevalence of lameness in children, since lameness is a common sequela of polio.

Question 2: What is **prevalence**?

Answer 2:
As with incidence, some people define prevalence as the number of cases (new and pre-existing), but most epidemiology textbooks define prevalence as the **proportion** of the population with a given condition or characteristic.

Prevalence (or prevalence rate) = $\frac{\text{all new and pre-existing cases during a given time period}}{\text{population during the same time period}}$

For the numerator, you need the total number of cases present in the District.
For the denominator, you need an estimate of the population from which the cases arose.

Prevalence can be further divided into point prevalence and period prevalence:
- Point prevalence is the proportion of persons with a disease, condition, or attribute in a population at a single point in time, often at the time of a survey.
- Period prevalence is the number of persons who have or have had a disease, condition, or attribute in a population during a specified period of time, often one year.

Question 3a: What data might you use (or collect) to determine the **incidence** of polio in the population?

Answer 3a
For a "reportable" disease, the number of new cases used in the numerator usually is based on the number of cases reported through the reportable disease surveillance system. To supplement the passive surveillance system, investigators may wish to review medical records in places in which the diagnosis is made, e.g., medical clinics, hospitals, etc. Information on **incident** cases could be collected by retrospectively reviewing medical records of previously recognized cases. Alternatively, a simple system could be established at the hospital to prospectively collect information on patients with polio at the time they are admitted to the hospital.

The denominator for surveillance data is the population of the geographic area, e.g., the population of the Ababo District. If the hospital catchment area includes areas outside Ababo, you have a choice. Either (1) include in the numerator cases occurring in residents of the areas outside Ababo and estimate the population of the hospital catchment area for the denominator (usually a difficult task), or (2) more conveniently, restrict both the numerator and denominator to Ababo residents by excluding the non-Ababo cases from the numerator.

Question 3b: What data might you use (or collect) to determine the **prevalence** of the sequelae of polio (lameness) in the population?

Answer 3b
Prevalence is usually assessed with a population-based survey. A population-based survey could determine the number of children with lameness as well as other health conditions and behaviors. The survey could concentrate on children of a particular age, such as 5-15 years or 12-23 months. The survey could also provide more specific denominator data by characterizing the age and sex distribution of the population.

The survey instrument should include enough information to allow the investigators to determine the prevalence of lameness consistent with polio (e.g., acute onset of flaccid paralysis rather than trauma or other causes), as well as the characteristics of affected (versus unaffected) children.

Question 4: What are the key elements included in the definition of public health surveillance?

Answer 4
Numerous definitions of surveillance exist. Two definitions are:

"the continued watchfulness over the distribution and trends of incidence through the systematic collection, consolidation, and evaluation of morbidity and mortality reports and other relevant data, [and the regular dissemination of these data to] all who need to know" (Langmuir, 1963)

"the ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know. The final link in the surveillance chain is the application of these data to prevention and control. A surveillance system includes a functional capacity for data collection, analysis, and dissemination linked to public health programs." (CDC, 1986)

The key elements of any definition of surveillance are:
- ongoing (as opposed to a one-time survey)
- systematic (standardized, to facilitate comparisons across space and time)
- collection
- analysis
- interpretation
- dissemination (to those who need to know to take action, and to those who provide reports)
- link to action (surveillance is sometimes called "information for action")

Question 5: What is the difference between **active** and **passive** surveillance systems? Is the Ababo surveillance system for polio passive or active?

Answer 5
Active and **passive** are from the perspective of the health department.

Passive surveillance = health care providers, hospitals, sometimes labs, etc. send reports to the health department based on a set of rules and regulations.

Active surveillance = health department staff call or visit health care providers on a regular basis (e.g., weekly) to solicit case reports.

Ababo has a passive surveillance system.

PART II

To characterize the incidence of polio over time, the new District Health Officer tabulated the routinely collected surveillance records for the past five years. In Ababo, the operational surveillance case definition for polio is acute onset of flaccid paralysis plus fever. The data are shown in Table 1.

The most recent census was conducted in 1986, when the population of the Ababo District was determined to be 360,000 persons. The population in Ababo is assumed to be growing at a constant rate of 3.8% per year.

Table 1. Polio Morbidity and Mortality, Ababo District, 1986-1990

Year	#New Cases	# Deaths	Midyear Population	Incidence Rate Per 100,000	Mortality Rate Per 100,000	Case-fatality Rate (%)
1986	54	5	360,000			
1987	56	7				
1988	50	6				
1989	68	8				
1990	74	10				

Question 6a: What is a case-fatality rate? What does it measure?

Answer 6a
The case-fatality rate is the proportion of persons with a particular condition who die from that condition.

Case-fatality rate = # deaths among incident cases / # incident cases x 10^n

The case-fatality rate is a measure of severity of illness.

Question 6b: Complete Table 1 by calculating the annual midyear population estimates, polio incidence rates, disease-specific mortality rates, and case-fatality rates for each of the past five years.

Answer 6b

Year	# New Cases	# Deaths	Midyear Population	Incidence per 100,000	Mortality per 100,000	Case-fatality Rate (%)
1986	54	5	360,000	**15.0**	**1.4**	**9.3%**
1987	**56**	**7**	**373,680**	**15.0**	**1.9**	**12.5%**
1988	**50**	**6**	**387,880**	**12.9**	**1.5**	**12.0%**
1989	**68**	**8**	**402,620**	**16.9**	**2.0**	**11.8%**
1990	**74**	**10**	**417,920**	**17.7**	**2.4**	**13.5%**

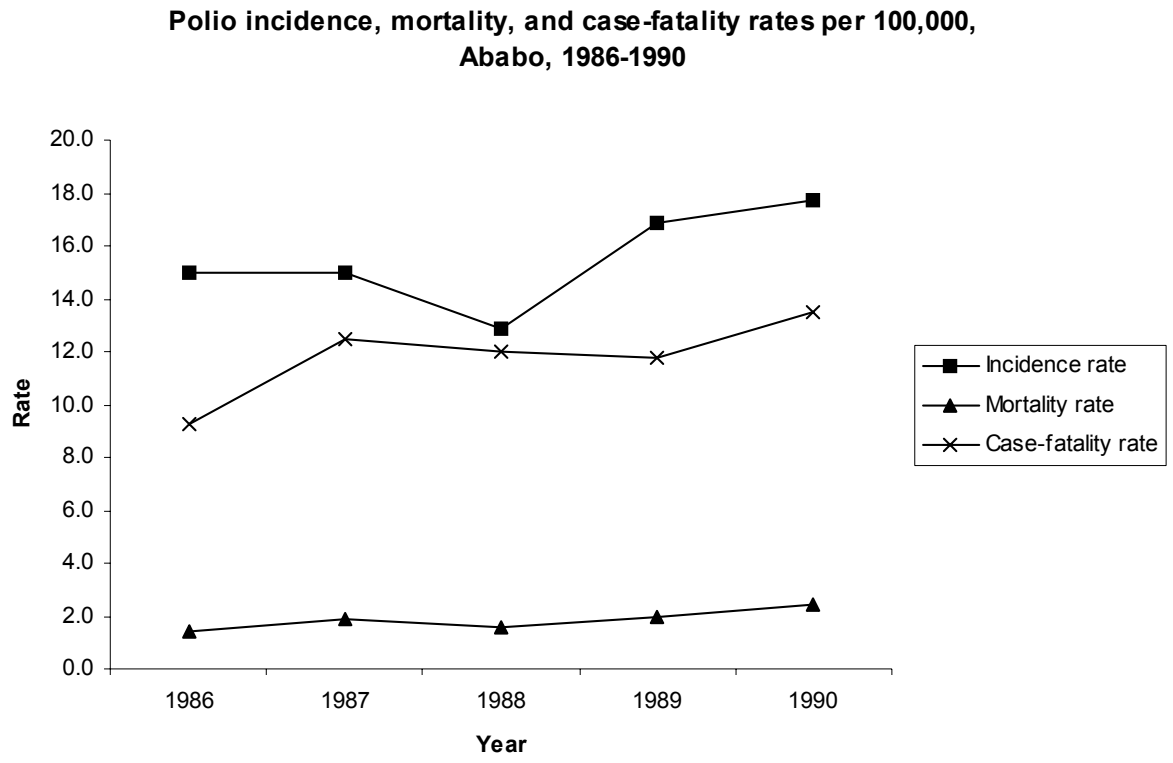
Question 7: Plot the trends in incidence rates, mortality rates, and case-fatality rates. Interpret these data.

Answer 7

This is an exercise in graphing. Either arithmetic or semilog graphs may be used. The title should tell what, where, and when; the axes should be properly labeled; the legends should be clearly marked, etc.

The incidence and mortality rates were roughly parallel, with an overall increasing trend despite a dip in the third year. The case-fatality rate was below 10% during the first year, and has fluctuated between 11.8% and 13.5% in subsequent years.

These data should be interpreted with extreme caution. Surveillance data usually undercounts the true incidence. The assumption of constant 3.8% population growth may be unrealistic. The variations seen may simply reflect random fluctuations, changes in the population size, changes in diagnosis and/or reporting, etc.



The District Health Officer is concerned that the number of reported cases seems low. He is concerned that **sensitivity** may be one of several weaknesses of the polio surveillance system.

Question 8a: Define **sensitivity**. If the sensitivity of the system is indeed low, can these data still be used to describe the trends?

Answer 8a

Sensitivity = the number of detected true cases / the total number of true cases. In other words, sensitivity is the ability of a system (or test, case definition, etc.) to detect the true cases.

If the sensitivity is low but relatively constant over time (e.g., in any given year about 20% of cases are reported), then the trends will still be valid. Unfortunately, this commonly made assumption is rarely evaluated in the real world.

Question 8b: In addition to sensitivity, what other attributes of a surveillance system should you evaluate in determining whether the system is meeting its objectives?

Answer 8b

In general, when evaluating a surveillance system, the following facets of the system should be addressed:

- The public health importance of the health event(s) under surveillance
- The objectives and operation of the system
- The system's usefulness
- Attributes of the system
- Cost or resource requirements of the system

Important attributes include:

- **Simplicity** - the ease of operation of the system as a whole and each of its components
- **Flexibility** - ability to accommodate changes in operating conditions or information needs
- **Data Quality** - completeness and validity of the data collected and recorded
- **Acceptability** - willingness of individuals and organizations to participate in the system
- **Sensitivity** - ability to detect the cases or health events or outbreaks it is intended to detect
- **Predictive Value Positive** - mostly affected by the system's specificity, PVP is the proportion of reported cases (or outbreaks) which truly are cases (or outbreaks)
- **Representativeness** - extent to which the system accurately portrays the incidence of the health event in a population by time, place, and person
- **Timeliness** - availability of data in time for appropriate action
- **Stability** - reliability and availability of the system (operates properly without failure)

Ref: CDC. Updated guidelines for evaluating public health surveillance systems: recommendations from the guidelines working group. *MMWR* 2001;50(No. RR-13):11-24.

Question 9: What might account for the increase in the number of new cases observed during the two most recent years?

Answer 9
The increase may be due to a **true** increase in incidence or to **artifact**.

A true increase may result from:
- increase in the size of the susceptible population (births, immigration, etc.)
- low vaccination coverage
- vaccine failure (primary = no immunity induced; secondary = waning immunity)
- change in the agent (virulent strain or antigenic shift away from vaccine type)
- vaccine-associated polio (Ref: CDC. Outbreak of poliomyelitis—Dominican Republic and Haiti, 2000. *MMWR* 2000;49:1094,1103.)

Artifactual reasons include:
- changes in local reporting procedures (e.g., easier reporting procedure like active rather than passive)
- changes in case definition (cf: AIDS)
- increased interest because of local or national awareness
- improvements in diagnostic procedures
- new health care worker(s) or facilities - may see more referred cases, may make the diagnosis more often, may report more reliably
- outbreak of similar disease, misdiagnosed as disease of interest
- laboratory error
- batch reporting

Depending on perspective, can be considered “real” or artifactual:
- change in denominator - influx of tourists (Cape Cod), refugees, migrant farmers, etc.

To characterize the population that has come down with polio in Ababo, the District Health Officer went to the hospital to review the charts of all children admitted with polio during the past two years. To his surprise, he found more cases with a discharge diagnosis of polio from the hospital in 1989 and 1990 than were reported from the whole district during the same years.

Question 10: How might you explain the discrepancy between the hospital cases and reported cases?

Answer 10
Not all the cases from the hospital are being reported. Possible reasons include:
- clinical case definition may differ from surveillance case definition
- misunderstanding about what is supposed to be reported
- misunderstanding about who is responsible for reporting (who is responsible? perhaps each staff worker thinks someone else will fill it out)
- lack of motivation among workers, or workers are too busy to fill out reports
- reports are filled out only for those with admission diagnosis, missing those diagnosed in hospital
- reports are misplaced, delayed, lost, miscoded, either at hospital or health department
- hospital has run out of forms

Recall that, in Ababo, the working surveillance case definition for polio was acute onset of flaccid paralysis plus fever. In reviewing the records, the Health Officer found that the data on signs and symptoms of children given the diagnosis of polio were not uniformly recorded. On most charts it was noted that the child had fever and acute onset of flaccid paralysis. On about 1/3 of the charts, however, there was no notation of fever but only the acute onset of paralysis.

Question 11: What is the effect of including the children without fever status recorded on the chart in your case definition?

Answer 11

A definition of fever plus paralysis will miss some true cases which do not have one or the other (decreased sensitivity), but will increase the likelihood that cases truly are polio (increased predictive value positive). In contrast, a definition of paralysis regardless of fever will increase the total number of cases. Some of these extra cases will indeed be polio, so the sensitivity is increased. On the other hand, some of these extra cases will be non-polio causes of paralysis, so the predictive value positive will actually decrease. (Casting a wider net catches more tuna, but also more dolphins.)

For your information, the WHO/PAHO standard case definitions are (Ref: Polio Eradication Field Guide, 2nd edition, PAHO,1994, p. 9-11):

SUSPECTED CASE A suspected case is *any acute onset of paralysis in a person less than 15 years of age* for any reason other than severe trauma OR paralytic illness in a person of any age in which polio is suspected. The classification of a suspected case is temporary and *within 48 hours* of notification should be reclassified as "probable" or "discarded."

PROBABLE CASE (Acute Flaccid Paralysis) A suspected case is classified as “probable” if *acute flaccid paralysis* (AFP) is found AND no other cause for the paralysis can be identified immediately. This classification of a probable case is also temporary; *within 10 weeks* of onset the case should be reclassified as "confirmed," “compatible,” “vaccine-associated,” or "discarded."

CONFIRMED CASE A confirmed case is one with acute paralytic illness with or without residual paralysis AND isolation of wild poliovirus from the stools of either the case or its contacts,

POLIO-COMPATIBLE CASE Cases are classified as “polio-compatible” when two adequate stool specimens were not collected from a probable case within 2 weeks of onset of paralysis AND there is either an acute paralytic illness with polio-compatible residual paralysis at 60 days OR death takes place within 60 days OR the case is lost to follow-up.

VACCINE-ASSOCIATED PARALYTIC POLIOMYELITIS Acute paralytic-illness in which vaccine-like poliovirus is isolated from stool samples AND the virus is believed to be the cause of the disease.

Returning to the office, the District Health Officer learns that the disease report forms have run out. He sees this as an opportunity to design a new disease report form.

Question 12: What types of information would you ask for on the new polio report form?

Answer 12
INSTRUCTOR'S NOTE: Break the class into groups of 3-5 students, have each group list the types of information on the board.

INSTRUCTOR'S NOTE: The type and amount of information really depends on the level of disease in the population. If incidence is high, you might only want to collect the total number of cases by week, for example. If incidence is low (close to eradication), you would want more detailed information to confirm the diagnosis, track exposures and contacts, etc.

For a low-incidence setting, the disease report form might include the following categories:
- **Patient identifying information** (name, address/village, [phone number, if applicable]) - allows call-backs, checks for duplicate reports, etc.
- **Demographic information** (age, sex, race/tribe) - allows characterization of populations at risk
- **Clinical information** (date of onset, signs/symptoms (including fever), lab, hospitalized? died?) - allows verification of case definition, characterization of spectrum and course of disease, impact on resources, etc.
- **Risk factors** (occupation, household contacts, travel, immunization status, etc.) - to help investigation, targeting of control, prevention measures
- **Reporter identifying information** (name, address, phone number, date of report) - allows follow-up, feedback

The hospital review identified a total of 150 cases of polio. Characteristics of the cases are provided in the following tables.

Table 2. Seasonal Distribution of Polio, Ababo District Hospital, 1989 and 1990

Month	1989	1990	Month	1989	1990
January	5	7	July	2	3
February	19	16	August	0	2
March	4	8	September	1	1
April	9	13	October	2	1
May	4	8	November	4	4
June	4	5	December	7	5

Question 13: Describe the seasonal occurrence of polio in Ababo. (Note that Ababo is in the Southern Hemisphere.)

Answer 13
Clear seasonal peak in February, March, into April (Ababo's summer, into Fall). This is consistent with the known seasonal distribution of polio.

Table 3. Age Distribution of Polio Cases, Ababo District Hospital, 1989 and 1990

Age (in years)	Number	Age (in years)	Number
<1	34	5	2
1	50	6	3
2	25	7	2
3	27	$8	0
4	7		

Question 14: Determine the median and mean age of cases.

Answer 14

Median = middle value (after the data have been ranked)

Steps to find median:

1. Arrange the data in increasing or decreasing order (already done)
2. Find the middle rank with the following formula:
   middle rank = $(n + 1) / 2 = (150+1)/2 = 75.5$th observation
3. Identify the value of the middle observation
   75th and 76th observation both fall in 1-year category, so median = 1 year

Usually, mean = $\Sigma x_i / n$

Age	# Cases	Age × # Cases
0	34	0
1	50	50
2	25	50
3	27	81
4	7	28
5	2	10
6	3	18
7	2	14
$8	0	0
		Sum = 251

Mean = 251 / 150 = 1.67 years

However, age is not rounded like most continuous variables, and the above calculation of the mean age can be criticized. Note that the average age of persons less than 1 year of age is 0.5 years. Similarly, the average age of children 1 year of age is actually 1.5. Therefore, the mean age should be calculated as follows:

Stated Age	Age midpoint	# Cases	Age × # Cases
<1	0.5	34	17.0
1	1.5	50	75.0
2	2.5	25	62.5
3	3.5	27	94.5
4	4.5	7	31.5
5	5.5	2	11.0
6	6.5	3	19.5
7	7.5	2	15.0
$8	8.5	0	0.0
			Sum = 326.0

Mean age = 326/150 = 2.17

A common mistake is to multiply the 34 cases under 1 yr. by the midpoint of the <1 yr interval (0.5), but then multiply the number of cases in the other age groups by the age in whole years. The result is 1.79. This result is not correct, since one must be consistent in using either age as a whole number or the midpoint of each age interval.

Table 4. Sex and Ethnic Distribution of Polio Cases, Ababo District Hospital, 1989 and 1990

	Sex		
	Male	Female	
Zanu	73	53	126
Hanzu	12	2	14
Other	8	2	10
	93	57	150

Question 15: What is the ratio of male to female cases?

Answer 15: 93:57 = 1.6:1

Question 16: Review the ethnic distribution of cases. Can you conclude, based on these results, that being a member of the Zanu tribe is a risk factor for polio? Why or why not?

Answer 16
No. We do not know what proportion of the population belongs to each ethnic group. The distribution of cases may simply reflect the distribution of ethnic groups in the population. In other words, Zanus may simply be the predominant group in Ababo. Risk is inferred from rates, which need denominators.

To gather information on polio prevalence, vaccine coverage, and risk factors for polio, the District Health Officer conducted a survey of children in the district. Lameness was used as a surrogate for polio. The prevalence of lameness by vaccination status is shown in Table 5.

Table 5. Lameness by Vaccination Status among Children 12-23 Months of Age, Ababo District, 1991

		Lame	Normal	Total
Polio Vaccine	$1 dose	1	242	243
	0 doses	9	667	676
		10	909	919

Question 17a: What is the prevalence of polio (lameness) among vaccinated ($1 dose) children?

Answer 17a: 1/243 = 0.4% = 411.5 per 100,000 children

Question 17b: What is the prevalence of polio (lameness) among the unvaccinated children?

Answer 17b: 9/676 = 1.3% = 1,331.4 per 100,000 children

Question 17c: What is the vaccine coverage (at least one dose) in this population?

Answer 17c: 243/919 = 26.4%

Question 17d: Interpret these data.

Answer 17d
The prevalence of lameness among the vaccinated group is about one-third the prevalence of lameness in the unvaccinated group (0.4% versus 1.3%, prevalence ratio = 0.3). Unfortunately, the proportion of children receiving at least one dose appears to be rather low, with only about a fourth of the eligible population vaccinated.

Students may ask whether you can calculate vaccine efficacy from these data. If one is willing to assume that prevalence of illness is a surrogate for the incidence of polio (and this assumption is tenuous at best), then vaccine efficacy = (1331.4 - 411.5) / 1331.4 = 69% for one or more doses of vaccine. Given that we do not know how many doses the children actually received, and given that prevalence of lameness may be a poor surrogate for incidence of polio, this value of 69% is largely uninterpretable!

The District Health Officer plans to review the polio surveillance data each month. Knowing that part of a good surveillance system involves disseminating the information to "those who need to know," the District Health Officer begins to compile a list.

Question 18: To whom should surveillance information be disseminated? How might you disseminate this information?

Answer 18:
Surveillance data should be distributed to "those who need to know." That includes:
- those who provide the data - health workers, hospitals, labs, etc.
- those who are responsible for acting on the data - public health program managers, field workers, policy makers
- those with oversight responsibility - Minister and staff, perhaps donor agencies
- others who are interested - village elders, public health (other districts, WHO, etc.), special interest groups, sometimes the public at large, etc.

Information could be disseminated by:
- newsletter
- annual report
- press releases
- scientific journal articles
- scientific (and public) meetings
- village presentations

A few months after the hospital chart review was completed, the medical officer on the hospital pediatric service called the District Health Officer. She has seen 12 and 34 cases in the months of January and February of 1991, respectively.

Question 19a: What is the expected number of cases for January and February?

Answer 19a
Using 1989 and 1990 as the baseline years, the expected number is simply the average number of cases in those months.

January: (5 + 7) / 2 = 6 expected cases

February: (19 + 16) / 2 = 17.5 expected cases

INSTRUCTOR'S NOTE: One could multiply these figures by 103.8% or so to account for growth in population, but the results will not be substantially different.

Question 19b: In your opinion, is Ababo experiencing an epidemic of polio?

Answer 19b
No right answer. The number of observed cases is almost exactly double the number of expected cases, which is a substantial increase. If the increase is not due to any of the artifactual reasons discussed in Question 9, then a doubling of cases would be considered an epidemic. However, given all the increased attention that District Health Officer has devoted to polio (improved surveillance, new form, survey, etc.), it is possible that the increase is due to increased reporting rather than increased incidence.

A meeting was held to discuss the situation. The results of the vaccine coverage survey were reviewed, and the authorities decided to launch an intensive polio vaccination campaign.

EPILOGUE

In 1988, the World Health Assembly launched a global initiative to eradicate polio by the end of the year 2000. This initiative was not without controversy. Some public health officials argued that polio, a potentially fatal or crippling disease, could be eradicated, so it should. In the long run, eradication would save billions of dollars. Others felt that the money and energy that would be expended in eradicating polio, a disease already of low prevalence in most countries, could be better spent on comprehensive public health interventions rather than a single disease, and that the eradication effort might divert time, attention, and resources from other programs.

From the inception of the Global Polio Eradication Initiative in 1988 to the end of 2002, the number of cases has fallen by over 99%, from an estimated more than 350 000 cases in 1988 to 1919 reported cases in 2002 (as of 16 April 2003). In the same time period, the number of polio-infected countries was reduced from 125 to 7. Polio is now found only in parts of Africa and south Asia. Meanwhile, polio surveillance is thought to have improved, with rates of detected acute flaccid paralysis (AFP) rising from 1.6 to 1.9 per 100,000 children <15 years of age between 2001 and 2002.

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3. WHO. *Poliomyelitis* (Fact Sheet no. 114). Geneva: WHO, April 2003.